International Review of Economics and Finance 45 (2016) 298–315

Contents lists available at ScienceDirect

International Review of Economics and Finance

journal homepage: www.elsevier.com/locate/iref

A representative agent asset pricing model with heterogeneous beliefs and recursive utility

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ARTICLE INFO

Article history:
Received 12 September 2014
Received in revised form 6 September 2015
Accepted 26 June 2016
Available online 2 July 2016

JEL classification:
E43
G12
G17

Keywords:
Heterogeneous beliefs
Recursive utility
Equity premium
Equity volatility
Yield curve

ABSTRACT

In this paper, we consider a continuous-time pure exchange economy with multiple agents whose preferences are represented by a time-inseparable recursive utility. Agents are homogeneous in their preferences, but heterogeneous in their beliefs regarding the drift rate of the aggregate endowment process. Given a competitive equilibrium in this economy, we construct a tractable representative agent model that would approximate asset prices in the original multiple agents economy. We show that our model helps resolve many asset pricing puzzles, such as the equity premium puzzle, equity volatility puzzle, risk-free rate puzzle, and term premium puzzle.

1. Introduction

In financial studies, there are many asset pricing puzzles that the standard model fails to explain. Among them, one of the most famous puzzles is probably the equity premium puzzle identified by Mehra and Prescott (1985). They have shown that the standard representative agent model under a pure exchange economy cannot replicate the historical average of excess equity returns over risk-free interest rates. Meanwhile, Backus et al. (1989) have shown that the standard model cannot explain the historical average of excess long-term bond returns over risk-free short rates. This is known as the term premium puzzle.

In addition, Weil (1989) has shown that the standard model implies an implausibly high risk-free rate, which is the risk-free rate puzzle. Furthermore, Shiller (1981) has shown that the volatility of equity prices is too high relative to the volatility of dividends. This is called the equity volatility puzzle. Considering that equity and bonds are the two most fundamental assets in financial markets, a unified model that can capture the main features of both asset prices is required.

For this purpose, this paper examines the effect of heterogeneity in the agents' beliefs on asset prices. We consider the standard continuous-time pure exchange economy model, in which the aggregate endowment follows the geometric Brownian motion with a constant drift and volatility. In our model, there are multiple agents who are homogeneous in their preferences, but heterogeneous in their beliefs about the drift rate of the aggregate endowment.[1]

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[1] We treat the belief heterogeneity among agents as given, and the cause of the heterogeneity is not a subject of interest for the current study. One possible explanation is that agents might consider the aggregate endowment process as ambiguous. If agents exhibit different attitudes toward this ambiguity, they would behave as if they have heterogeneous beliefs.

http://dx.doi.org/10.1016/j.iref.2016.06.009
1059-0560/

This study assumes that agents have a common preference of the stochastic differential utility (SDU) proposed by Duffie and Epstein (1992), which is a continuous-time analogue of the recursive utility modeled by Epstein and Zin (1989) and Weil (1989). This preference separates the agents' attitude toward intertemporal substitution from their attitude toward risk. As Borovicka (2012) shows, this separation is necessary for agents with inferior beliefs to survive in the long-run. Therefore, to analyze the long-run effect of belief heterogeneity on asset prices, we should consider something beyond the conventional time-separable constant relative risk aversion (CRRA) utility.

By assuming SDU, we show that the cross-sectional dispersion in consumption growth rates among agents, which originates from belief heterogeneity, enters into the drift rate of the aggregate stochastic discount factor (SDF). We then propose a tractable representative agent model, where the discount rate of the agent is modified to reflect the belief heterogeneity. And, we show that the time-varying discount rate of the representative agent is a key ingredient in our model to resolve the asset pricing puzzles cited above simultaneously.

When the agents' relative risk aversion (RRA) is less than unity, the discount rate of the representative agent is lower than that under the homogeneous belief economy. This decrease in the discount rate should lower the average level of short-term risk-free rates, which can resolve the risk-free rate puzzle. In addition, our calibration indicates that the discount rate of the representative agent fluctuates counter-cyclically. This counter-cyclical variation in the discount rate should amplify the pro-cyclical variation in long-term asset prices, including the price of equity and discount bonds, which should help resolve the equity volatility puzzle. Furthermore, strong correlations between long-term asset prices and aggregate consumption increase the risk premiums for both equity and discount bonds, which contribute toward resolving the equity premium puzzle and the term premium puzzle.

1.1. Literature overview

A large body of literature has analyzed the effect of belief heterogeneity on asset prices. Among them, Admati (1985); Wang (1993); Brennan and Cao (1996), and others attribute the belief heterogeneity to asymmetric information, while Harrison and Kreps (1978); Harris and Raviv (1993); Jouini and Napp (2007); David (2008); Bhamra and Uppal (2014), and others assume belief heterogeneity exogenously. The latter approach is known as “agree to disagree” or a “difference in opinion”, and the current study belongs to this strand of literature.

This paper is closely related to the analysis of Jouini and Napp (2007). By assuming a time-separable utility, they construct a representative agent whose SDF replicates asset prices under the original multi-agent economy. They show that the belief of the representative agent corresponds to the weighted average of agents' beliefs, while the dispersion in agents' beliefs is incorporated into the discount rate of the representative agent. Their result suggests that a representative agent model endowed with the average belief among agents is insufficient to account for belief heterogeneity.

While allowing belief heterogeneity, most papers cited above (including Jouini and Napp, 2007) assume a common preference among agents.[2] Furthermore, most papers assume time-separable CRRA utility as a standard in asset pricing studies. Because the homotheticity of CRRA utility produces stationary asset returns, it is suited for analyzing the long-run moments of asset returns. However, as Kogan et al. (2009) and Yan (2008) show, if agents have a common time-separable CRRA utility, those agents with inferior beliefs cannot survive in the long-run under the general equilibrium setting. Therefore, if some agents in the economy have correct beliefs, the economy will converge to the representative agent model with the correct belief. That is, as long as time-separable CRRA utility is assumed, the belief heterogeneity has only a temporary effect on asset prices.

By assuming a two-agent economy with common time-inseparable SDU preferences, Borovicka (2012) has recently shown that an agent with inferior beliefs could survive in the long-run. In particular, when the agents' RRA is higher than the inverse of their intertemporal elasticity of substitution (IES), there can be some non-degenerate equilibria, where both agents affect asset prices in the long-run. Therefore, as long as a common preference is assumed in the setting of heterogeneous beliefs, it is necessary to isolate the agents' RRA from their IES in order to analyze the unconditional moments of asset returns. This fact motivates us to extend Jouini and Napp's (2007) model to include the case of SDU preference.

Assuming SDU preference with high values for both RRA and IES, in itself, helps resolve the equity premium puzzle and the risk-free rate puzzle. In particular, when the agents' RRA is higher than the inverse of IES, the agents prefer an early resolution of uncertainty. Unfortunately, this preference for early resolution should deepen the term premium puzzle because the agents would prefer long-term bonds to short-term bonds in order to hedge the persistent uncertainty. Therefore, if there was no belief heterogeneity, the term premium should be negative.[3] Our model succeeds in generating positive term premiums because the belief heterogeneity produces a counter-cyclical variation in the discount rate of the representative agent. This counter-cyclical variation in the discount rate makes long-term bonds more risky than short-term ones, and agents should require positive risk premiums when holding long-term bonds.

Considering the extensive volume of consumption-based asset pricing literature, there are very few studies that account for the equity premium puzzle and the term premium puzzle simultaneously. For example, under a standard exchange economy model, Savov (2011) resolves the equity premium puzzle as well as the risk-free rate puzzle by using a novel measure of aggregate consumption. Ai (2010) also resolves the equity premium puzzle by introducing agents' learning into the Bansal and Yaron's (2004) long-run risk model under a

[2] One exception is Bhamra and Uppal (2014) who allow heterogeneity in both beliefs and preferences. However, in order for agents with inferior beliefs to survive in the long-run, they should impose rather tight restrictions on the relationship between the agents' beliefs and preferences.

[3] Piazzesi and Schneider (2006) analyze the shape of equilibrium yield curves under the case of homogeneous beliefs with recursive utility. While they replicate the upward slope of “nominal” yield curves by introducing inflation risk, their “real” yield curves are downward sloping.